| Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Army | | | | | | | | | | | Date: February 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Appropriation/Budget Activity<br>2040: *Research, Development, Test & Evaluation, Army* / BA 2: *Applied Research* | | | | | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | | | | | | | |
| **COST ($ in Millions)** | **Prior Years** | **FY 2017** | **FY 2018** | **FY 2019 Base** | **FY 2019 OCO** | **FY 2019 Total** | **FY 2020** | **FY 2021** | **FY 2022** | **FY 2023** | **Cost To Complete** | **Total Cost** |
| Total Program Element | - | 72.979 | 58.352 | 58.283 | - | 58.283 | 57.741 | 59.224 | 59.519 | 63.663 | 0.000 | 429.761 |
| EM4: *Electric Component Technologies (CA)* | - | 18.000 | 0.000 | 0.000 | - | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 18.000 |
| EM8: *High Power And Energy Component Technology* | - | 11.000 | 10.632 | 12.584 | - | 12.584 | 13.150 | 13.386 | 13.684 | 16.316 | 0.000 | 90.752 |
| H11: *Tactical And Component Power Technology* | - | 8.396 | 8.332 | 7.658 | - | 7.658 | 7.854 | 8.050 | 7.017 | 5.181 | 0.000 | 52.488 |
| H17: *Flexible Display Center* | - | 2.266 | 2.143 | 0.000 | - | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.409 |
| H94: *Elec & Electronic Dev* | - | 33.317 | 37.245 | 38.041 | - | 38.041 | 36.737 | 37.788 | 38.818 | 42.166 | 0.000 | 264.112 |

**A. Mission Description and Budget Item Justification**

This Program Element (PE) designs and evaluates power components and power management technologies, frequency control and timing devices, high power microwave devices, display technologies, and electronic components. The applied research on these technologies enable the ability to perform precision deep fires against critical mobile and fixed targets; investigate all-weather, day or night, theater air defense against advanced enemy missiles and aircraft; as well as investigate enhanced communications and target acquisition through support of capabilities such as autonomous missile systems, advanced land combat vehicles, smart anti-tank munitions, electric weapons, secure jam-resistant communications, automatic target recognition, foliage-penetrating radar, and combat identification. Project EM8 designs and evaluates high-power electronic components and technologies. Project H11 designs, investigates and validates advanced power and energy technologies (batteries, alternative energy and hybrids) and power management and distribution techniques (wireless power, intelligent power management). Project H17 designs and evaluates flexible displays in conjunction with the Flexible Display Center. Project H94 researches and evaluates electronic component technologies such as photonics, micro electromechanical systems, imaging laser radar, magnetic materials, ferroelectrics, microwave and millimeter-wave components, and electromechanical systems.

Work in this PE complements and is fully coordinated with efforts in PE 0602120A (Sensors and Electronic Survivability), PE 0602307A (Advanced Weapons Technology), PE 0602709A (Night Vision Technology), PE 0602782A (Command, Control, Communications Technology), PE 0602783A (Computer and Software Technology), PE 0603001A (Warfighter Advanced Technology), PE 0603004A (Weapons and Munitions Advanced Technology), and PE 0603772A (Advanced Tactical Computer Science and Sensor Technology).

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

Work is performed by the Army Research, Development, and Engineering Command (RDECOM).

| Exhibit R-2, RDT&E Budget Item Justification: PB 2019 Army | Date: February 2018 |
|---|---|
| **Appropriation/Budget Activity**<br>2040: *Research, Development, Test & Evaluation, Army I* BA 2: *Applied Research* | **R-1 Program Element (Number/Name)**<br>PE 0602705A *I Electronics and Electronic Devices* |

| B. Program Change Summary ($ in Millions) | FY 2017 | FY 2018 | FY 2019 Base | FY 2019 OCO | FY 2019 Total |
|---|---|---|---|---|---|
| Previous President's Budget | 56.322 | 58.352 | 59.780 | - | 59.780 |
| Current President's Budget | 72.979 | 58.352 | 58.283 | - | 58.283 |
| Total Adjustments | 16.657 | 0.000 | -1.497 | - | -1.497 |
| • Congressional General Reductions | - | - | | | |
| • Congressional Directed Reductions | - | - | | | |
| • Congressional Rescissions | - | - | | | |
| • Congressional Adds | 18.000 | - | | | |
| • Congressional Directed Transfers | - | - | | | |
| • Reprogrammings | - | - | | | |
| • SBIR/STTR Transfer | -1.326 | - | | | |
| • Adjustments to Budget Years | - | - | -1.497 | - | -1.497 |
| • FFRDC | -0.017 | - | - | - | - |

| Congressional Add Details ($ in Millions, and Includes General Reductions) | FY 2017 | FY 2018 |
|---|---|---|
| **Project:** EM4: *Electric Component Technologies (CA)* | | |
| Congressional Add: *Silicon Carbide (SiC) Research-Army Research Laboratory* | 10.000 | - |
| Congressional Add: *Tactical and component power technology* | 2.000 | - |
| Congressional Add: *Payload agnostic unmanned aerial systems* | 4.000 | - |
| Congressional Add: *Flexible printable electronics* | 2.000 | - |
| Congressional Add Subtotals for Project: EM4 | 18.000 | - |
| Congressional Add Totals for all Projects | 18.000 | - |

**Change Summary Explanation**

FY17 Congressional increase in EM4 Electric Component Technologies

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | | Date: February 2018 |
|---|---|---|---|
| Appropriation/Budget Activity<br>2040 / 2 | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | Project (Number/Name)<br>EM4 / *Electric Component Technologies (CA)* | |

| COST ($ in Millions) | Prior Years | FY 2017 | FY 2018 | FY 2019 Base | FY 2019 OCO | FY 2019 Total | FY 2020 | FY 2021 | FY 2022 | FY 2023 | Cost To Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EM4: *Electric Component Technologies (CA)* | - | 18.000 | 0.000 | 0.000 | - | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 18.000 |

**Note**

Congressional increases for tactical and component power technology ($2M); Payload agnostic unmanned aerial systems ($4M); Silicon carbide research ($10M); Flexible printable electronics ($2M)

**A. Mission Description and Budget Item Justification**

Congressional Interest Item funding for Electronic Component applied research.

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 |
|---|---|---|
| ***Congressional Add:*** Silicon Carbide (SiC) Research-Army Research Laboratory<br>***FY 2017 Accomplishments:*** N/A | 10.000 | - |
| ***Congressional Add:*** Tactical and component power technology<br>***FY 2017 Accomplishments:*** N/A | 2.000 | - |
| ***Congressional Add:*** Payload agnostic unmanned aerial systems<br>***FY 2017 Accomplishments:*** N/A | 4.000 | - |
| ***Congressional Add:*** Flexible printable electronics<br>***FY 2017 Accomplishments:*** N/A | 2.000 | - |
| **Congressional Adds Subtotals** | 18.000 | - |

**C. Other Program Funding Summary ($ in Millions)**

N/A

**Remarks**

**D. Acquisition Strategy**

N/A

**E. Performance Metrics**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | | | | | | | | | | Date: February 2018 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Appropriation/Budget Activity<br>2040 / 2 | | | | | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | | | | Project (Number/Name)<br>EM8 / *High Power And Energy Component Technology* | | | |
| **COST ($ in Millions)** | **Prior Years** | **FY 2017** | **FY 2018** | **FY 2019 Base** | **FY 2019 OCO** | **FY 2019 Total** | **FY 2020** | **FY 2021** | **FY 2022** | **FY 2023** | **Cost To Complete** | **Total Cost** |
| EM8: *High Power And Energy Component Technology* | - | 11.000 | 10.632 | 12.584 | - | 12.584 | 13.150 | 13.386 | 13.684 | 16.316 | 0.000 | 90.752 |

**A. Mission Description and Budget Item Justification**

This Project provides for the research, development, and evaluation of high-power electronic components, materials, and related technologies. These technologies have application in compact and efficient power conversion, conditioning, and management sub-systems; energy storage and conversion devices; radio frequency (RF)/ microwave and solid-state laser directed energy weapons (DEW); traditional and non-traditional RF and laser electronic attack; and RF photonics. All project elements are coordinated with, and as appropriate leveraged by, DEW and power/energy programs in the Air Force, Navy, High Energy Laser Joint Technology Office, Defense Threat Reduction Agency, national labs, university consortia, and relevant industry and foreign partners. The products of this research are required by developers of Army and Department of Defense (DoD) systems to evolve traditional (mechanical-based) sub-systems such as geared transmissions, plate armor, and kinetic projectiles to electrically-based ones. These products will provide the Soldier enhanced survivability and lethality through increased power management and energy savings as well as new fighting capabilities offered only by electrical power.

This Project sustains Army science and technology efforts supporting the Ground Maneuver, Lethality, Soldier and Command, Control, Communications and Intelligence Portfolios.

The work in this Project is coordinated with the Army Tank and Automotive Research, Development, and Engineering Center (TARDEC); Armaments Research, Development, and Engineering Center (ARDEC); the Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC); and the Army Communications-Electronics Research, Development, and Engineering Center (CERDEC); and the United States Army Space and Missile Defense Command/Army Forces Strategic Command (USASMDC/ARSTRAT).

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Title:*** Advanced Solid-State Laser Technology and Integrated Photonic Technologies | 2.000 | 2.006 | 2.000 |
| ***Description:*** Research novel solid-state laser concepts, architectures, and components with the goal of providing advanced laser technology to Army directed energy weapon and tactical laser developers. Exploit breakthroughs in laser technology, develop and employ innovative laser gain material, and utilize photonics to meet the stringent weight/volume requirements for Army platforms, especially to enhance and improve the generation, transmission, reception, and processing of radio frequency (RF) signals. Applied laser research will be conducted in close collaboration with domestic and foreign material vendors, university researchers, and major laser diode manufacturers | | | |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>EM8 / *High Power And Energy Component Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***FY 2018 Plans:***<br>Investigate innovative glass fiber laser architectures and bulk solid state laser materials and designs best suited for high energy per pulse operation with emphasis on low size, weight and power (SWAP) for applications including track illuminator lasers for directed energy weapons, Joule-class pulsed in-band Midwave-Infrared (MWIR) sources for imaging sensor defeat, and Longwave Infrared (LWIR) illuminators for operation in degraded visual environments; and develop structures, devices, and architectures to enable optical phased arrays capable of handling high peak power transmission and low loss reception.<br>***FY 2019 Plans:***<br>Will investigate innovative fully crystalline fiber designs, in particular, the ?crystalline core/crystalline cladding? design (a.k.a. CCCC or C4) developed to enable high energy laser power scaling out of single fiber laser aperture to >10X compared to the current state-of-the-art; will explore alternative Raman fiber designs for power scaling of direct diode cladding pumped Raman fiber lasers; and will develop structures, devices, and architectures to enable optical phased arrays capable of free space optical communications and ranging, and timing and position synchronization needed for mobile platforms.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Slight decrease due to reduced material cost. | | | |
| ***Title:*** Electronic Attack Technologies/Spectrum Sensing and Exploitation<br>***Description:*** This effort investigates emerging technologies related to electronic warfare (EW) applications, non-kinetic survivability/lethality, and emerging concepts of operation, such as cognitive radar, in the increasingly contested and congested electromagnetic environment, with the goal of enhancing the survivability/lethality of Army platforms through electronic attack (EA), electronic warfare support (ES), and electronic protection (EP).<br>***FY 2018 Plans:***<br>Develop multi-device waveform packages for counter unmanned aerial vehicle (CUAS) EA applications; explore distributed low-cost ES sensors and applications to enhance situational awareness and enable novel and precise EA capabilities; investigate next-generation radar EP performance in a complex electromagnetic environment; develop a cognitive spectrum sensing test-bed with advanced signal processing algorithms to support EP and RF spectrum exploitation objectives such as cognitive radar; and design and develop a full array of Cyber Electromagnetic Activities (CEMA) to investigate and validate the impact on developmental technologies and systems.<br>***FY 2019 Plans:***<br>Will develop neutralization techniques for autonomous vehicles; will investigate remote determination of target susceptibility; and will explore next-generation cognitive radar performance in realistic congested and contested spectral environment. Will | 2.346 | 2.456 | 1.888 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>EM8 / *High Power And Energy Component Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| design and develop electronic attack (EA), electronic warfare support (ES), and electronic protection (EP) tools, techniques and methodologies for the highest priority Army systems and technologies for which electronic warfare is a critical threat.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Decreased investments in spectrum sensing and exploitation to support new starts. | | | |
| ***Title:*** Electronic Components and Materials Research<br><br>***Description:*** Investigate compact, high-efficiency, high-temperature, and high-power component technologies (e.g., semiconductor, magnetic, and dielectric devices) for hybrid-electric propulsion, electric power generation and conversion, and smart micro-grid power distribution. Research addresses current and future Army-unique performance and operational requirements.<br><br>***FY 2018 Plans:***<br>Investigate ultrawide-bandgap power devices, architectures, and materials for power switching and distribution; modify and validate high voltage physics-based model to support gallium nitride (GaN)-based devices to provide better understanding of device operation and physics for improved reliability and performance; conduct analysis of motor operation at high frequency or high voltage to determine feasibility of high torque, low revolutions per minute (RPM) motors; investigate high frequency circuit topologies and, through modeling and component analysis, determine reliability and performance of circuit designs; investigate designs, materials, and additive manufacturing processes that enable low cost, high performance power device packaging; research aluminum (AlGaN) material properties leading to the growth of high speed transistors and diode devices; and explore AlGaN structures by varying substrate and epitaxial growth conditions.<br><br>***FY 2019 Plans:***<br>Will perform measurements on aluminum gallium nitride (AlGaN) high electron mobility transistor (HEMT) devices to demonstrate improved efficiencies and breakdown characteristics based on enhanced ohmic contacts, locally doped p-type regions using ion implantation, and AlGaN films grown on either high quality GaN or aluminum nitride (AlN) substrates; will refine high speed motor drive model and utilize model to study wide bandgap (WBG) device performance; will characterize WBG device performance using the motor test stand; and will investigate WBG devices for high speed high voltage motor drives and tactical power conversion.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increased investments to advance the development of wide bandgap materials. | 3.264 | 2.993 | 3.190 |
| ***Title:*** Power System Components Integration and Control Research | 3.390 | 3.177 | - |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>EM8 / *High Power And Energy Component Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Description:*** Research the configuration of electronic components and control strategies required to achieve high-power density and high-efficiency power utilization in current and future platform sub-systems, and vehicle and micro-grid (installation) applications, to include the operation of military-specific power distribution topologies at the circuit and system levels.<br><br>***FY 2018 Plans:***<br>Investigate control methods and components that enable reconfigurable power conversion based on varying voltage to reduce the size, weight, and power of conductors in constrained applications; investigate concepts for compact and efficient high voltage power distribution topologies and control methodologies for continuous power applications; analyze and model concepts for significantly reducing the volume of high-voltage power conditioning circuits for use in projectiles and other compact lethality and protection systems; develop designs and control methodologies for novel, low voltage alternating current (AC) and direct current (DC) distributed control and storage technologies to improve energy efficiency of Army tactical energy networks; develop underpinning electric- and magnetic (E/H)-field technologies to support persistent power and energy monitoring of microgrid infrastructures and other systems; and develop algorithms to robustly characterize E/H-field multi-scale events in complex noise environments.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Effort ends in FY18. | | | |
| ***Title:*** Advanced Distributed Power for Autonomous Plaforms | - | - | 1.506 |
| ***Description:*** The effort investigates power distribution and conversion technologies to provide compact, efficient, and high power capabilities for electrical and electro-mechanical loads supporting both mobile and stationary platforms. High voltage and intelligent control methods will be coupled with the ongoing research in autonomy technologies to provide advanced performance enhancements in mobility and capabilities for these platforms. Research on innovative electric machines covering both electrical generation and motor technologies will focus on providing efficient, power dense, fault tolerant generation and mobility capabilities. Research addresses current and future Army-unique power delivery challenges in compact autonomous air and ground platforms.<br><br>***FY 2019 Plans:***<br>Will investigate power control topologies that provide low speed high torque motor operation; will explore power distribution and conversion methods for power generation that enhance fault tolerance and provide graceful degradation; will investigate high voltage switching and power packaging for application in conversion and distribution for autonomous platform mobility and power generation; and will perform research in compact power switching, conversion and distribution technologies to produce fast, high energy electrical discharge to provide unique mobility enhancements through application of high voltage phenomenology.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:*** | | | |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>EM8 / *High Power And Energy Component Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| New focus area beginning in FY19. | | | |
| ***Title:*** RF Electronic Attack/Surveillance (Grey C3)<br>***Description:*** Investigate emerging technologies to enable electronic warfare (EW) applications in a grey environment. The goal is to develop software and reconfigurable radio frequency (RF) hardware in a handheld form factor for distributed electronic attack, distributed EW support, and communications. EW support includes advanced passive and active RF sensing.<br>***FY 2019 Plans:***<br>Will investigate techniques for distributed Electronic Attack (EA) and Electronic Warfare Support (ES) from handheld platforms; and will validate commercial off-the-shelf (COTS) and government off-the-shelf (GOTS) software-defined radios for use as surrogate development hardware.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>New focus area beginning in FY19. | - | - | 2.000 |
| ***Title:*** Vulnerability Analysis Methodology for CEMA threats<br>***Description:*** Research and investigate the optimum configuration of experimental and analysis methodology for separate and combined cyber and electromagnetic threat attack so as to better support and inform Army system designers, analysts, evaluators, and decision makers.<br>***FY 2019 Plans:***<br>Will design and develop a vulnerability analysis and susceptibility profile methodology based on current simulation and experimental methods for cyber and electromagnetic threats. Will investigate and validate methodology to improve Protect, Detect, React, and Restore assessments through automation and advanced analytics.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>New focus area beginning in FY19. | - | - | 2.000 |
| **Accomplishments/Planned Programs Subtotals** | 11.000 | 10.632 | 12.584 |

**C. Other Program Funding Summary ($ in Millions)**

N/A

**Remarks**

**D. Acquisition Strategy**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>EM8 / *High Power And Energy Component Technology* |

**E. Performance Metrics**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | | Date: February 2018 |
|---|---|---|---|
| Appropriation/Budget Activity<br>2040 / 2 | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | Project (Number/Name)<br>H11 / *Tactical And Component Power Technology* | |

| COST ($ in Millions) | Prior Years | FY 2017 | FY 2018 | FY 2019 Base | FY 2019 OCO | FY 2019 Total | FY 2020 | FY 2021 | FY 2022 | FY 2023 | Cost To Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H11: *Tactical And Component Power Technology* | - | 8.396 | 8.332 | 7.658 | - | 7.658 | 7.854 | 8.050 | 7.017 | 5.181 | 0.000 | 52.488 |

**A. Mission Description and Budget Item Justification**

This Project identifies, advances, and enhances emerging power generation, energy storage, and power management components and software. This Project researches advancements in enabling power management, rapid decision making, expeditionary maneuver, and distributed operations across the battlefield. This Project also researches materials and components to develop lightweight, higher capacity, safer and more efficient power technologies that will enable continuous and energy aware operations while on the move and across battlefield environments.

The cited work is consistent with S&T priorities of the U.S. Army Chief of Staff, the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Title:*** Tactical Power Generation Technology | 3.830 | 3.625 | 2.946 |
| ***Description:*** This effort designs, investigates and validates Soldier-borne power generation and energy storage technologies in order to decrease Soldier load and power burden, and increase power capabilities by providing more energy to prolong mission run-time. This effort will investigate energy harvesting devices while on the move which will enable a continuous operations and reduced logistics for the Soldier. This effort will also investigate advanced hybrid battery chemistries for wearable, flexible battery designs. | | | |
| ***FY 2018 Plans:***<br>Investigate and evaluate improvements to generator component technologies in energy harvesting devices for power conversion efficiency and enable more power generation on the move for near NetZero (produces as much energy as it uses) operations; investigate advanced lithium primary and rechargeable battery chemistries that are low cost and have the potential to double the runtime of current battery technology; conduct lab experiments on advanced battery cells configured with new chemistries, electrodes and electrolytes to validate the stability of the formulation and improvements in capacity; develop cell components to further improve the usable capacity within the ballistic battery to enable 20+ hours of continuous power; investigate fuel reformation techniques along with advanced materials to develop a small form factor, multi-fueled, wearable power source. | | | |
| ***FY 2019 Plans:***<br>Will complete optimization of electromechanical component technology designs in kinetic energy harvesting devices for maximum power generation and conversion efficiency to enable continuous, distributed operations; continue investigation of power generating techniques with significant power densities including ultra-capacitor technology; complete the optimization and | | | |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H11 / *Tactical And Component Power Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| integration of high voltage cathode materials into representative battery cells to validate designs and assess energy density advancements; complete the development of Silicon Anode and Lithium Sulfur cell materials for advanced lithium primary and rechargeable battery cell packs that enables a 2x improvement in performance; research novel chemistries and balance of plant materials for smaller, lighter, wearable / portable fueled power sources to enable continuous power generation and platoon battery charging.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Investment reduction in rechargeable battery chemistry research in order to support senior leader Network priorities. | | | |
| ***Title:*** Energy Informed Operations<br>***Description:*** This effort investigates power management technologies, components and systems to increase the efficiency of energy output, reduce weight and increase reliability, while increasing fuel and cost efficiency across battlefield environments. This effort funds research in control and interface standards for effective power management, novel power distribution techniques, situational awareness, predictive, and prognostic and diagnostics capabilities for tactical power missions. This effort will also investigate scalable brass board designs for power management and distribution in support of missions in the 60 kilowatt (kW) ? 360kW range. Work in this effort complements Program Element (PE) 0603772A/Project 101.<br>***FY 2018 Plans:***<br>Simulate power micro-grid architecture, standards and interface specification for controller software and expand and update interface specification for software and physical architecture design to more efficiently distribute and manage power across the battlefield based on results of simulation; explore a domain-based approach for standards for distributed micro-grid; investigate performance and design of smart power generation and distribution devices such as generators, inverters, distribution boxes, energy storage and renewable energy systems, that can be managed, monitored and controlled by Soldiers or autonomously to prioritize load, reduce fuel consumption and ensure reliable mission power based on a distributed, rather than a centralized control approach; design architecture and software to incorporate wireless data technologies for the purpose of reducing power loss, complexity of setup and startup, and weight in power distribution systems; investigate the use of secure wireless internet (WiFi) and power line carrier methods to transmit control and status signals; analyze novel wireless power transmission technologies such as far field (for distances over 0.25 kilometers) power transfer based on microwave and laser power transmission technologies.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Effort ends in FY18. | 4.566 | 4.707 | - |
| ***Title:*** Optimized Energy for C4ISR Platforms | - | - | 4.712 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H11 / *Tactical And Component Power Technology* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Description:*** This effort investigates power and thermal management associated with high power Command, Control, Communications, computers, Intelligence, Surveillance and Reconnaissance (C4ISR) capabilities on ground and air platforms enabling enhanced mobility and mission flexibility. This effort funds research to improve platform efficiency through the use of on-demand hybrid power architectures, while also researching ways to eliminate platform thermal constraints. This effort will also investigate very high density power sources and energy storage for high rate pulsed power, power management and thermal management for dynamic high rate pulsed power. Work in this effort complements Program Element (PE) 0603772A/Project 101.<br><br>***FY 2019 Plans:***<br>Will investigate power requirements for emerging C4ISR capabilities to include directed energy, lasers, high power sensors, and electromagnetic weapons; conduct analysis of size, weight and power requirements necessary to support these capabilities with unique very high density power sources and energy storage for high rate pulsed power; identify interface requirements and constraints for power system; investigate architectures and intelligent controls necessary to manage these loads; investigate and perform high resolution characterization of cyclical, step and high power load profiles likely to result from use of lasers or other high power, short duration burst technology; examine thermal implications and waste heat generated from inefficiencies in power conversation; explore hybrid energy storage technologies to support cyclical loads such as hybrid batteries or ultra-capacitor technology; determine duel use potential of microwave or laser power transmission technologies with other developmental operational uses; conduct experiments on wireless power transmission capabilities for laser power transmission; explore the use of intelligent control strategies for platform integrated power systems.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Investment to support C4ISR power requirements in support of Network/C3I senior leader priorities. | | | |
| **Accomplishments/Planned Programs Subtotals** | 8.396 | 8.332 | 7.658 |

**C. Other Program Funding Summary ($ in Millions)**

N/A

**Remarks**

**D. Acquisition Strategy**

N/A

**E. Performance Metrics**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | | Date: February 2018 |
|---|---|---|---|
| Appropriation/Budget Activity<br>2040 / 2 | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | Project (Number/Name)<br>H17 / *Flexible Display Center* | |

| COST ($ in Millions) | Prior Years | FY 2017 | FY 2018 | FY 2019 Base | FY 2019 OCO | FY 2019 Total | FY 2020 | FY 2021 | FY 2022 | FY 2023 | Cost To Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H17: *Flexible Display Center* | - | 2.266 | 2.143 | 0.000 | - | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.409 |

**A. Mission Description and Budget Item Justification**

The flexible electronics program conducts applied research on the integration of electronics, power components, and sensors on non-traditional flexible substrates. The program builds upon two-dimensional (2D) flexible electronics to incorporate the integration of electronic components, power systems, and sensors into three-dimensional (3D) flexible architectures. The research includes electronic modeling, design, fabrication, and analysis. The applied research supports the demonstration of Army-relevant sensors on flexible substrates for Army applications such as monitoring of the human state.

This project supports Army science and technology efforts in the Command, Control, Communications and Intelligence portfolio.

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas.

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Title:*** Flexible Electronics Development (previously Flexible Display Center (FDC) and Flexible Electronics Development) | 2.266 | 2.143 | - |
| ***Description:*** The flexible electronics program is advancing applied research towards the integration of electronics, power components, and sensors on non-traditional flexible substrates and into three-dimensional (3D) architectures.<br><br>***FY 2018 Plans:***<br>Investigate hybrid 3D printed sensors with integrated silicon (Si) complementary metal-oxide-semiconductor (CMOS) electronics; investigate co-design of algorithms, power distribution, and 3D printed sensors and electronics for extended duration monitoring of soldier's physiological and environmental state; examine and develop noise resistant and computationally efficient algorithms coupled to distributed sensing and computation hardware to enable real-time estimate of the human physiological state; investigate hardware, algorithms, and architectures to enable efficient, robust physiological monitoring of individuals within small, distributed groups; and will develop silicon-fiber based liquid metal inductors; and develop and improve the fabrication process for stretchable gallium nitride (GaN) in silicon, which enables electronic monitoring of Soldiers? performance on or close to the skin without discomfort.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Effort ends in FY18. | | | |
| **Accomplishments/Planned Programs Subtotals** | 2.266 | 2.143 | - |

**C. Other Program Funding Summary ($ in Millions)**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H17 / *Flexible Display Center* |

**C. Other Program Funding Summary ($ in Millions)**

**Remarks**

**D. Acquisition Strategy**

N/A

**E. Performance Metrics**

N/A

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | | Date: February 2018 |
|---|---|---|---|
| Appropriation/Budget Activity<br>2040 / 2 | R-1 Program Element (Number/Name)<br>PE 0602705A / *Electronics and Electronic Devices* | Project (Number/Name)<br>H94 / *Elec & Electronic Dev* | |

| COST ($ in Millions) | Prior Years | FY 2017 | FY 2018 | FY 2019 Base | FY 2019 OCO | FY 2019 Total | FY 2020 | FY 2021 | FY 2022 | FY 2023 | Cost To Complete | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| H94: *Elec & Electronic Dev* | - | 33.317 | 37.245 | 38.041 | - | 38.041 | 36.737 | 37.788 | 38.818 | 42.166 | 0.000 | 264.112 |

**A. Mission Description and Budget Item Justification**

This Project designs and characterizes electronics, electronic components, and electronic devices for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) applications and battlefield power and energy applications. Significant areas of component research relevant to C4ISR include: antennas, millimeter wave components and imaging, micro- and nano-technology, eye-safe laser radar (LADAR), vision and sensor protection, infrared (IR) imaging, photonics, and prognostics and diagnostics. Areas of research relevant to power and energy include power and thermal management, micro-power generators and advanced batteries, fuel reformers, fuel cells for hybrid power sources, and photosynthetic routes to fuel and electricity.

This Project supports Army science and technology efforts in the Command Control and Communications, Soldier, Ground and Air portfolios. Work in this Project is fully coordinated with PE 0602709A (Night Vision Technology), PE 0603001A (Warfighter Advanced Technology), PE 0603004A (Weapons and Munitions Advanced Technology), PE 0603005A (Combat Vehicle and Automotive Advanced Technology), PE 0603008A (Command, Control, Communications Advanced Technology), PE 0603313A (Missile and Rocket Advanced Technology) and PE 0603772A (Advanced Tactical Computer Science and Sensor Technology).

The cited work is consistent with the Assistant Secretary of Defense, Research and Engineering Science and Technology priority focus areas.

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| ***Title:*** Antennas, Microwave Components, and Millimeter Wave Imaging | 4.707 | 5.733 | 5.681 |
| ***Description:*** This effort designs, characterizes, and validates high performance antennas, microwave components, and software for multifunction radar, radio frequency (RF) sensing, and communication systems. Research areas include scanning techniques, broadbanding, beamforming, polarization, platform integration, and affordability. For microwave components, research areas include software defined radios, analog-to-digital conversion rates, bandwidth resolution, bit accuracy, circuit design and affordability. | | | |
| ***FY 2018 Plans:***<br>Develop an analytical methodology that will define key electrical parameters for antenna optimization; use this methodology to define electrical parameters in computer simulations; develop experimental antennas exploiting previous materials development work at ARL; investigate devices and materials for two-dimensional (2D) steering of millimeter-wave radar beams for applications such as helicopter collision avoidance in degraded visual environments; design, fabricate, and characterize gallium nitride (GaN)-based integrated circuits for multi-mode radar applications; examine techniques to achieve compact, linear RF front-end components to increase radar range and sensitivity; mature RF micro-electromechanical system (MEMS)-enabled electronics for | | | |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| cognitive and adaptable radio and electronic warfare systems; and investigate small, low-power sensors and control systems for use by Soldiers and in unmanned applications.<br><br>***FY 2019 Plans:***<br>Will perform in-situ simulations of low-profile antennas and propagation; integrate and characterize new antenna and RF electronics to improve the performance of the helicopter situational awareness radar and study the fusion of these radars with other hostile fire sensor modalities; enhance efforts for material driven antenna designs to include evolving antenna additive manufacturing through the investigation of higher dielectric feed stock and conductive printed metals; produce novel, complex and conformal multiband array designs that are not cost effective to produce with current commercial materials; design enabling components for transmitter architectures that supports complex digital modulations in the presence of very strong nonlinearities; study enabling devices and integrated circuits at millimeter-wave frequencies at the advent of 5G and newly competed spectrum; develop machine learning techniques/algorithms for RF modulation recognition.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Slight decrease due to maturity of MEMs-based electronics. | | | |
| ***Title:*** Advanced Micro and Nano Devices<br><br>***Description:*** This effort designs and characterizes micro- and nano-technology components for multi-functional and integrated radio frequency (RF) applications, micro-robotics, integrated energetics, control sensor interfaces, and sensors for improved battlefield situational awareness. Work being accomplished under PE 0601102A / Project H47 (Applied Physics Research) complements this effort.<br><br>***FY 2018 Plans:***<br>Explore 2D stacked electronic materials and tunable electronic properties for multifunctional integrated RF circuits; mature piezoelectric-enabled RF micro-electromechanical system (MEMS) components for cognitive and adaptable radio and electronic warfare systems; and investigate integration of on-chip energetic materials for low-cost electronic device protection.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Effort ends in FY18. | 2.155 | 1.947 | - |
| ***Title:*** Survivability for Wireless Tactical Networks (formerly Security and Survivability for Wireless Tactical Networks )<br><br>***Description:*** This effort researches, designs and implements protocols and algorithms for networks of physical devices and autonomous systems operating under severe energy and bandwidth constraints, and which are vulnerable to adversarial infiltration. The objective is to enhance the performance and survivability of these tactical wireless networks through improved monitoring and detection of network problems, resulting from both adversarial activity and the operating environment, and through proactive adaption of the computer and network routers to these dynamics. In FY 2019, realigned funds moved out of this effort | 1.439 | 1.567 | 0.750 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| remain in support of the Army science and technology (S&T) priorities (cyber) as identified at the December 2016 S&T Army Requirements Oversight Council by the Chief of Staff of the Army.<br><br>***FY 2018 Plans:***<br>Investigate and implement scheduling algorithms that dynamically adapt based on local- and network-wide conditions; investigate network capacity improvement techniques; and develop machine learning approaches for detecting, characterizing, diagnosing, and defeating potentially malicious activities in networks of physical devices and autonomous systems.<br>***FY 2019 Plans:***<br>Will investigate and develop cognitive networking algorithms that optimize media access control scheduling and network routing in resource constrained (e.g. energy, processing), congested and contested environments; implement energy and computationally efficient techniques to determine if resource constrained devices have been infiltrated and corrupted by an adversary; investigate approaches for adapting and optimizing communication modalities in response to adversarial activity; implement techniques for simulating and emulating large scale networks to enable analyzing the behavior of complex systems of networks in complex tactical operating environments.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Investments decreased due to development of technologies for anti-access/area denial. | | | |
| ***Title:*** Sensor Protection<br>***Description:*** This effort develops and characterizes materials for protection of electro-optic (EO) systems from lasers.<br><br>***FY 2018 Plans:***<br>Deposit electro-optical (EO) materials for protection on substrates with very high thermal conductivity to provide improved temperature control and reduced power consumption in fast EO shutter devices; and optimize active protection concepts in the infrared (IR) for improved speed and threat laser wavelength rejection.<br>***FY 2019 Plans:***<br>Will mature EO materials and supporting electronic components; validate speed and degree of protection of large-area EO shutters; conduct experiments to determine performance of tunable longwave IR filter designs.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increase in investments to develop tunable electro-optical material - based filters. | 2.780 | 2.914 | 4.925 |
| ***Title:*** Applied Photonic and Optoelectronic Devices (formerly Hazardous Material Detection)<br>***Description:*** This effort models and develops materials and devices for the next generation Army sensor systems. Semiconductor materials and devices from ultraviolet (UV) to infrared (IR) with active and passive imaging capabilities will be modeled and | 1.910 | 1.957 | 2.141 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| developed. This will allow the Soldier to maintain situational awareness day and night under cluttered battlefield conditions. Sources and detectors for next generation secure battlefield communication devices will also be developed. For asymmetric threats, chemical sensing devices will also be studied and developed.<br><br>***FY 2018 Plans:***<br>Characterize, and model mechanisms in semiconductor materials that can reduce thermal noise in IR devices and allow them to operate at higher temperatures, reducing the need for cryogenic cooling; model and simulate to improve IR system-level performance; model and develop energy efficient, compact semiconductor ultraviolet (UV) laser sources and detectors for short-range, non-line-of-sight communications; and develop interfaces to connect biochemical signal detection with on-chip photonics and electronics for improved detectors.<br><br>***FY 2019 Plans:***<br>Will conduct 3-D modeling of the device properties of mercury cadmium telluride semiconductor structures that utilize novel resonant architectures or carrier depletion techniques to reduce dark current and increase operating temperature of IR detectors and thereby reduce the need for cryogenic cooling; design and develop near ultraviolet laser sources based upon semi-polar and non-polar III-Nitride semiconductor heterostructures to enable compact and low cost ion-based quantum devices for networking; continue development and characterization of molecularly imprinted polymers as a chemical detection filter / concentrator for studying asymmetric threats.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increased investments to support development of novel III-Nitride materials. | | | |
| ***Title:*** Power and Thermal Management for Small Systems<br><br>***Description:*** This effort investigates, designs, and fabricates micro-electromechanical system (MEMS)-based components to improve power generation and micro-cooling technology for both dismounted Soldier and future force applications.<br><br>***FY 2018 Plans:***<br>Improve the size, weight, and packaging of electronics with higher thermal handling characteristics; and utilize excess heat through thermal-to-electric conversion for more energy efficient electronics via new materials, device technologies and structures, as well as the use of novel physical phenomena.<br><br>***FY 2019 Plans:***<br>Will demonstrate integrated thermophotovoltaic generator with overall system efficiency improved through an integrated heat recuperator and demonstrate multiple "simple" fuels, including single component hydrocarbons and surrogate fuels for more | 2.026 | 0.891 | 0.903 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| complex fuels like JP-8; use experimental results to validate models developed as part of this objective for the different fuel and catalyst material combinations.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increase due to inflation. | | | |
| ***Title:*** Advanced Infrared Technology<br><br>***Description:*** This effort designs and characterizes materials, components, and focal plane arrays (FPAs) for the next generation of night vision systems, missile seekers, and general surveillance devices. Materials and devices investigated include mercury cadmium telluride (MCT) and resonant quantum well infrared photodetector (R-QWIP) arrays for the long-wave infrared (LWIR) spectral region with goals to increase the operating temperature and decrease the cost of FPAs. Additionally, modeling of infrared device performance, at both the device and system levels, is being performed for all major infrared systems (MCT, R-QWIP, indium antimonide (InSb), and strained layer superlattices) of importance to the community. | 1.584 | - | - |
| ***Title:*** Power and Energy<br><br>***Description:*** This research focuses on the design and characterization of chemistries, materials, and components for advanced batteries, fuel reformers, and fuel cells. Potential Army applications include hybrid power sources, smart munitions, hybrid electric vehicles, and Soldier power applications. Additionally, investigate the applicability of photosynthesis to provide fuel and electricity for Soldier power applications, and investigate silicon carbide (SiC) power module components that could enable compact, high efficiency, high temperature, and high power density converters for motor drive and pulse power applications. The research accomplished under PE 0601104A/Project VS2 (multi-scale modeling) complements this effort.<br><br>***FY 2018 Plans:***<br>Investigate the deactivation mechanism of hydrocarbon combustion catalysts through in-situ studies with advanced spectroscopy and electron microscopy and develop strategies to design highly active and durable catalyst materials for compact power generation; develop improved electrolytes for high voltage storage chemistries; optimize development of high voltage electrolytes, additives and cathodes for energy density and safety; improve rise time and duration of thermal batteries within size, weight and power (SWAP) constraints; and develop an acid-alkali fuel cell membrane electrode assembly.<br><br>***FY 2019 Plans:***<br>Will improve the efficiency of dual intercalation electrodes for inexpensive grid energy storage; investigate additives to limit dendrite formation of lithium metal batteries for high energy density rechargeable batteries; investigate all-solid-state chemistries for safe lithium batteries; analyze and interpret the results of the investigation of new methods for reduced aging improved duration of thermal batteries performed in FY18; determine through modeling or conducting experiments the performance of these methods; investigate nanocomposite non-noble catalysts and acid-alkaline bipolar membrane electrolyte interface and single cell | 2.837 | 2.783 | 1.671 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| performance; integrate semipermeable membrane materials and electrolytes via hybrid bi-cell and bipolar membrane technologies to address costs and balance-of-plant issues.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Decrease in investments to support novel energy harvesting technologies. | | | |
| ***Title:*** Energy Harvesting<br><br>***Description:*** This research develops technologies to substantially reduce the number of batteries required to accomplish dismounted Soldier/Squad mission objectives, thereby significantly reducing Soldier-borne load and logistics requirements. Research will explore technologies to harvest electrical power by converting and storing energy via engineered structures and electronic bandgaps, micro-electromechanical system (MEMS)-based micro-scale power conversion, and heterogeneous 3D assembly of MEMS with other devices to enable efficient, distributed power conversion. Research explores novel paths to local fuel and energy production, including artificial photosynthesis, to extract hydrogen and electricity directly from water and sunlight.<br><br>***FY 2018 Plans:***<br>Develop photo-corrosion mitigation strategies that enable stable photo-electrolysis to produce hydrogen gas; develop catalysis process for faster electron transfer; create engineered polarization in gallium nitride devices; develop highly mismatched alloy material with good electronic and optical properties for water molecule splitting; develop spectral emission/transmission with spectrally tailored bandgap cells to increase far-field thermo-photovoltaic conversion efficiency; and develop polariton modes between emitter and cell to increase conversion efficiency and power density.<br><br>***FY 2019 Plans:***<br>Will incorporate broad-angle anti-reflection / rear surface light trapping structure matched to response spectrum of optimized hybrid quantum-mechanical based solar cell; investigate novel thermal energy harvesting including elastocalorics and pyroelectrics; develop plasmonically enhanced water and urea splitting device; develop the capability of enhancing catalytic reactions using infrared radiation; develop antimonide-doped gallium nitride water splitting device; demonstrate methanol production from Carbon Dioxide ($CO_2$) through reduction processes in the present of sunlight.<br><br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Enhanced investments in energy harvesting to develop tactical-unit energy independent solutions. | 2.524 | 2.764 | 3.022 |
| ***Title:*** Energy Efficient Electronics & Photonics<br><br>***Description:*** This effort addresses sustainment operations by unburdening the Soldier and reducing logistics requirements (e.g., fewer batteries) for communications, computing, and sensing. The objective is to improve the underlying energy efficiency of supply and demand for Soldier-portable and unattended sensor electronics to enable the dismounted Soldier to maintain communications, freedom of movement, and increase mission duration. The majority of the electronics power used by the | 4.869 | 5.538 | 5.523 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|

dismounted Soldier and by unattended sensors is attributable to radio frequency (RF) communications. In addition, freedom of movement and action during sustained and high tempo operations requires seamless battery recharging. To address these challenges, energy efficient electronics research includes RF circuits, devices, materials and wireless power distribution. Energy efficiency improvements will be developed and investigated in support of five key sensor and electronic areas: RF component devices, passively powered components, low-power, long-lived sources, wireless power transfer, and advanced battery chemistries. Additionally, materials and devices used for photonic applications, such as laser diodes and fiber lasers, will be studied and improved with an emphasis on overall size, weight, and power consumption efficiency gains.

***FY 2018 Plans:***

Explore heterogeneous integration of efficient III-V and II-VI semiconductor devices with leading edge process technology to enable small form-factor, highly linear RF circuits; examine digital back-end accelerators for implementing realistic communication waveforms at substantially reduced power; explore energy efficiency improvements by utilizing sub-threshold RF front-ends and high efficiency and high linearity analog components; investigate vertical and lateral carrier transport in semiconductor laser diode structures for the development of large area UV emitters; investigate the use of water-in-salt electrolytes to increase voltage window of supercapacitors and lithium-ion batteries and investigate the use of lithium sulfide (LiS) electrolytes for improved safety and improved energy storage; increase coulombic efficiency of dual intercalation electrodes for inexpensive grid energy storage; investigate additives to limit dendrite formation of lithium (Li) metal batteries for high energy density rechargeable batteries; investigate solid-state chemistries for safe Li batteries; investigate enhanced acoustically-coupled inductive wireless power transfer; reduce circuit power consumption through the design and fabrication of passively powered ambient sensors that enable zero power sleep mode for electronics; and develop extremely low power, intelligent power management for low power, long-life electronics.

***FY 2019 Plans:***

Will design and fabricate advanced node silicon and gallium nitride integrated circuits implementing Soldier Radio Waveform with 3X reduction in power draw; characterize carrier transport in semiconductor laser diode structures for the development of large area UV emitters; investigate processes to make 3-D electrode structures and investigate their effect on energy storage chemistry rates and ionic and electronic transports; investigate solid-state chemistries for safe lithium batteries; develop micro-electromechanical system (MEMS)-based and resonant RF sensors that can passively sense an RF signal while consuming < 10 nW of power for zero-power-consuming sleep mode electronics; determine the efficiency and power transfer limits of laser-to-pyroelectric wireless power transfer; explore acoustic power transfer with the ability to steer the acoustic beam source using arrays of acoustic transducers; design and develop near-ultraviolet laser sources based upon semi-polar and non-polar III-nitride semiconductor heterostructures to enable compact and low cost ion-based quantum devices for networking.

***FY 2018 to FY 2019 Increase/Decrease Statement:***

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| Slight decrease in solid-state chemistries for safe lithium batteries. | | | |
| ***Title:*** Precision Measurement Technology for Contested Environments (Technologies for Anti Access / Area Denial) | 2.512 | 2.941 | 2.983 |
| ***Description:*** This research focuses on technologies that will enable precise and assured position, navigation and timing in global positioning system (GPS)-denied environments. The first objective of this research is to improve the size, weight, power, cost, and accuracy of current micro-Inertial Measurement Systems (IMS) through the design, and fabrication of micro-electromechanical system (MEMS) gyroscopes. The second objective is to develop an opto-electronic device that can be used as an ultra-precise local oscillator with improved stability for precision timing applications. The third objective is to address the ability to transmit jam-resistant precision timing signals by investigating the transmission of precision, synchronized timing signals over optical fibers and free-space using lasers. The fourth objective is to explore new radio frequency (RF) antenna concepts to extend the reach of IMS systems through pseudolites (ground-based substitutes for GPS satellites) and Soldier-borne systems, and to integrate multiple sensor modalities with the IMSs using sensor fusion techniques to reduce drift and increase positional accuracy.<br><br>***FY 2018 Plans:***<br>Characterize and analyze the residual frequency instability of a free-space, laser-based frequency transfer system that could be used to synchronize the Army's positioning, navigation and timing (PNT) devices in the absence of signals from GPS; mitigate environmentally induced noise sources to increase the timing stability on optical-electronic devices used for precision timing; investigate and develop MEMS inertial sensors, aiding sensors, and sensor fusion approaches to enable navigation-grade inertial measurement units for assured PNT; conduct simulations and explore development of a new technique for anti-jam GPS antennas distributed on the human body; develop methods for night-time three-dimensional reconstruction using thermal imagery for autonomous navigation and detection of medium to low emissivity surfaces (e.g., metals) at night to assist warfighters in locating manmade targets; and develop methods for real-time vegetation and land classification for aiding position/locality determination.<br><br>***FY 2019 Plans:***<br>Will develop robust object recognition, efficient simultaneous localization and mapping and interactive topological mapping methods and integrate them into low size, weight and power - Cost (SWAP-C) platforms; investigate novel information sources to passively locate humans in a complex and cluttered environment; design, fabricate and characterize an integrated MEMS and heterogeneous sensor solution for increased state estimation accuracy; improve PNT sensor fusion algorithms to include input from a heterogeneous array of aiding sensors in diverse environments; assemble wearable anti-jam GPS test- bed and study performance of body-distributed anti-jam GPS antennas in laboratory environment; design and characterize an asymmetric free-space optical link that uses a retro-reflector to measure the time delay between the transmitter and receiver and uses a modulated laser to develop low SWAP-C free-space optical time transfer techniques; investigate deep learning based approaches for perception, including scene, landmark and skyline recognition on computationally constrained platforms to enable geo-localization | | | |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| without GPS; continue to develop and optimize material fabrication process for construction of environmentally stable Epsilon-Near-Zero oscillator materials and devices.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increase due to inflation. | | | |
| ***Title:*** Anti-Tamper (AT) Technology Development<br>***Description:*** This effort develops tools, devices, and techniques to protect acquisition program systems and Critical Program Information (CPI) from adversarial threats. This work is executed by the Army Anti-Tamper Office located at the Aviation and Missile Research, Development and Engineering Center (AMRDEC) at Redstone Arsenal, AL.<br>***FY 2018 Plans:***<br>Mature Anti-Tamper (AT) tools, techniques and Intellectual Property (IP) for projects Rigor 1 and Rigor 1a; complete design of architecture-level AT integration technologies; continue development of threat-based sensors and secure processor Intellectual Property (IP); finalize contractual scope and tape-out for production of parts from Trusted Foundry; and receive and begin laboratory characterization of Rigor devices.<br>***FY 2019 Plans:***<br>Will develop threat-based sensors and secure processor Intellectual Property (IP) to support Rigor technology refresh; manufacture full Rigor 1b engineering models; complete laboratory characterization of Rigor 1b module; continue design and development of Rigor 1a module; develop Rigor 1a test-modules.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Enhanced investments to enable development of threat-based sensors. | 3.974 | 5.025 | 6.050 |
| ***Title:*** Cognitive Countermeasures Technology Development<br>***Description:*** This effort investigates and matures novel materials, components, and techniques to counter legacy and emerging threats to Army platforms. Emphasis will be placed on technologies and approaches to enable a robust, holistic countermeasure capability for target defeat, regardless of threat characteristics or guidance mode.<br>***FY 2018 Plans:***<br>Design, model, and characterize advanced laser materials and architectures with low size, weight, power and cost to improve pulsed laser output energy for aircraft survivability applications; investigate self-amplification of cascade Er:Y2O3 laser in Cr:ZnSe; and explore potential for radio frequency technologies to enable early warning threat detection.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:*** | - | 2.010 | - |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

| B. Accomplishments/Planned Programs ($ in Millions) | FY 2017 | FY 2018 | FY 2019 |
|---|---|---|---|
| Effort ends in FY18. | | | |
| ***Title:*** Technologies for Alternative Energy<br>***Description:*** Design and develop novel concepts of energy generation, energy capture materials, and component technologies for efficient conversion of ambient energy to electrical energy for use and storage. Design components to include microscale power devices for multimodal harvesting and efficient distributed power conversion.<br>***FY 2018 Plans:***<br>Investigate catalyzing carbon dioxide (CO2) to longer chain hydrocarbons for energy storage; design a photo-electrochemical cell for studying CO2 conversion to a fuel; develop cost effective energy storage solutions for microgrid applications to enable renewable resource integration; and develop advanced concepts that lead to the development of nanophotonic components for energy harvesting and optimization of hybrid nanostructured materials for more efficient solar energy conversion.<br>***FY 2019 Plans:***<br>Will develop improved thermoelectric materials, with a goal of >2X improvement (>10%) conversion efficiency for low temperature differences near 1000 C; assemble and validate battery or pseudo-capacitor packs for both electrochemical and safety.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Increase due to inflation. | - | 1.175 | 1.191 |
| ***Title:*** Quantum for Assured PNT in Zero-GPS Environments Acceleration<br>***Description:*** To develop quantum-based GPS-independent ultra-high precision PNT in a contested/gps denied battlespace for mission durations up to 7 days w/o external timing or position re-synchronization. This effort also enables Camouflage, Concealment, and Decoys (CC&D) in an Electronic Warfare (EW) space and synchronization of disaggregated platforms / fires across the battlefield for distributed sensing, processing, and lethal effect.<br>***FY 2019 Plans:***<br>Designing of integrated triaxial Microelectromechanical systems (MEMS) Internal measurement units (IMUs) with 3 orders of magnitude improvement in accuracy (goal TRL4 in FY21), develop approach/design for integrated photonics and quantum timing circuit that meets PNT timing requirements while meeting on Soldier SWAP-C goals, and to build optical time synchronization demonstration for FY20/TRL3 demonstration.<br>***FY 2018 to FY 2019 Increase/Decrease Statement:***<br>Effort supports C3I/Network senior leader priorities. | - | - | 3.201 |
| **Accomplishments/Planned Programs Subtotals** | 33.317 | 37.245 | 38.041 |

| Exhibit R-2A, RDT&E Project Justification: PB 2019 Army | | Date: February 2018 |
|---|---|---|
| **Appropriation/Budget Activity**<br>2040 / 2 | **R-1 Program Element (Number/Name)**<br>PE 0602705A / *Electronics and Electronic Devices* | **Project (Number/Name)**<br>H94 / *Elec & Electronic Dev* |

**C. Other Program Funding Summary ($ in Millions)**

N/A

**Remarks**

**D. Acquisition Strategy**

N/A

**E. Performance Metrics**

N/A